ULTRASOUND ASSISTED ADSORPTIVE REMOVAL OF SUGARCANE AMINO ACIDS FROM AQUEOUS SOLUTION USING LOW COST GREEN ADSORBENTS

A

Synopsis

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By

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ORIGIN OF PROBLEM

Carbons were the first materials to be applied to adsorption process (e.g. the Phoenicians first recorded the use of charcoal to purify water in 460 BC). The sugar industry in England (towards the end of the 18th century) is credited with the first use in an industrial process of charcoal and carbons of animal origin (i.e. for decoloring sugar syrups and its use in sugar decolorization) [1-2]. In the last twenty years many new adsorptive materials have been developed. These materials include activated carbon fibers and molecular sieves, microporous glasses and nano-porous materials made from carbonaceous and inorganic materials. The concept of pore size engineering has also been considerably advanced [3].

Carbon adsorption is customary in food processing industries, such as sugar refining and for pollution control as in waste water treatment. In the proposed research work, green adsorbent materials synthesized from agricultural waste material have been presented. The selected agricultural based waste materials are easily available, relatively low cost, promising result and effectively produced could be our priority to replace non- renewable commercial activated carbon which is used in sugar refining process. Ultrasonic is an effective purification and separation technique used in industry especially in wastewater treatment.

Thus, the present piece of work is aimed to remove sugarcane amino acids from aqueous media using low-cost agricultural based green adsorbent materials developed from agricultural by-product-based waste materials (***Sugarcane Bagasse Ash, Rice Husk Ash and Corn Cob Ash***) in the presence and absence of Ultrasound (US).

Introduction

1.1 Background of the Study

Sugarcane is one of the most abundant crops on earth, forming major source of crystal sugar and other sweetening agents for human consumption. Sugarcane i.e. *'Saccharum officinarum'* is said to be in existence in Papua New Guinea, for over 12,000 years which is considered its original habitat. Sugar is an important commodity in world agricultural trade. It is mainly sucrose, a disaccharide made up of glucose and fructose, and is sourced from either sugar cane (*Saccharum officinarum* L.) or sugar beet (*Beta vulgaris* L.). Sugar obtained from sugar cane contributes to 70% of the world's sugar

production. However, unlike sugar beet, which is primarily sold as white sugar, a plethora of sugar products are produced from sugar cane (*e.g.*, raw sugar, syrup and molasses). Sugarcane spread to South East Asia and India in the course of few thousand years [4]. The modem vacuum pan cane sugar industry in India owes its origin to the first enterprises of Englishmen who at the beginning of the twentieth century set up half a dozen sugar factories in Uttar Pradesh (U.P.) in India. Another important landmark in the historical development of the Indian Sugar Industry was the release of new varieties of sugarcane as a result of the pioneering breeding research work at the Sugarcane Breeding Institute established in 1912.

1.2 Present State of Knowledge

Overview of India's sugar sector, Sugar industry in India after textile is the second largest agriculture-based industry. First sugar mill in India was established in 1930. Currently about 4 million hectares of land in India is under sugarcane with an average yield of 70 tons per hectare. The geographical distribution of sugarcane production in India is shown in ***Figure 1***. Sugar industry in India is concentrated in states of Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Haryana and Punjab. Growth of the sugar industry in India [5] is described below in ***Table 1*** [http://www.indiansugar.com].

Table 1: Growth of the sugar industry in India

Particulars	2012-13	2013-14	2014-15	2015-16	2016-17	2017-2018	2018-2019
No. of Factories in operation	507	529	526	509	538	526	497
Cane acreage (Thousands Hectares)	4885	5100	5279	5341	5307	5284	4945
Sugar Production (Lakh Tons)	3424	3538	3544	3456	3668	3369	3036
Molasses Production (Thousands Tons)	10970	11824	11744	10882	12482	10837	9026

The sugar sector is an important pillar of the Indian economy as it provides livelihood to 50 million farmers and to 5 million workers directly employed in sugar factory [6]. Besides this it creates

employment in ancillary services in transportation and trade etc. At present sugar sector's output worth is Rs.80, 000crore.

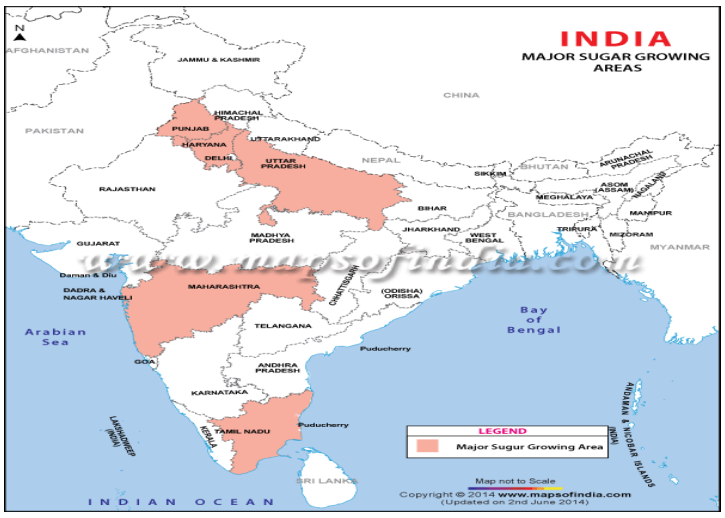


Figure 1: Geographical distribution of sugarcane production in India
(Source: https://testbook.com/blog/wp-content/uploads/2016/05/Crops-in-India-GK-Notes-in-PDF.pdf)

1.3 The Sugar Mills in India

India produces 18-20 million tons of sugar per year, making it the second largest sugar producer in the world. There are at least 550 sugar mills in India, distributed among 19 states, grinding 1250-2500 tons cane per day [5-6]. The main cane producing states and the number of mills in respective states are mention below:

States	No. of Mills
Maharashtra	193
Uttar Pradesh	148
Karnataka	58
Andhra Pradesh	38
Tamil Nadu	48
Gujarat	22

Most sugar plants in India produce the direct consumption sugar known as plantation mill white sugar (PMWS). It is produced from milled cane using double suffixation process.

1.4 Commercial Activated Carbon (CAC)

Adsorption techniques employing solid sorbents are widely used to remove certain classes of chemical pollutants from waters, especially those that are practically unaffected by conventional biological wastewater treatments. However, amongst all the sorbent materials proposed, activated carbon is the most popular for the removal of pollutants from wastewater [7]. Due to their great capacity to adsorb pollutants, CAC are the most effective adsorbents. This capacity is mainly due to their structural

characteristics and their porous texture which gives them a large surface area, and their chemical nature which can be easily modified by chemical treatment in order to increase their properties. However, activated carbon presents several disadvantages [8]. It is quite expensive, the higher the quality, the greater the cost, non-selective and ineffective against disperse and vat dyes. The regeneration of saturated carbon is also expensive, not straightforward, and results in loss of the adsorbent. The use of carbons based on relatively expensive starting materials is also unjustified for most pollution control applications [9]. This has led many workers to search for more economic adsorbents. The efficiency of any adsorbent material to adsorb the desired compounds (colour, ash, colloids) depends on several factors [10] such as porosity, surface area, pore size distribution, bulk density, surface chemistry, hardness, pH, particle density, particle size, amount of water soluble minerals and its total ash content.

1.5 Industrial Applications of Commercial Activated Carbon (CAC)

The activated carbon has wide industrial applications. Among these are:

1. To remove of small concentration of products, this may have no colour, taste, or odor, but which cause poor crystal yield or poor crystal habit.

2. To remove of trace quantities of impurities having no original colour, but subject to oxidation or other changes which may develop colour at a later stage of processing, or after the product has been packaged and sold (colour precursors) [11].

3. To remove of constituents causing foam or other undesirable surface-active phenomena, which interfere with other plant processes such as evaporation, agitation, or air-blowing.

4. To remove of impurities causing haze or turbidity, including those which do not precipitate out until after the product is sold (haze precursors, causing poor shelf life resulting in the product being returned by dissatisfied customers) [12-13].

2. Ultrasonic Purification and Separation Technique

Ultrasonic is an effective purification and separation technique used in industry especially in wastewater treatment. Ultrasonic generates high-energy which causes the cavitation. Cavitation is the rapid and repeated formation and resulting implosion of micro bubbles in a liquid resulting in the propagation of microscopic shock waves. Microscopic vapor bubbles are created at site of rarefaction

as the liquid fractures or tears because of the negative pressure of the sound wave in the liquid. Finally, the compression part, which follows the rarefied part, collapses the bubble. The cavitational collapse of bubble generates localized hot spots of temperature as high as 5000K and pressure of as high as 1000 atmospheres for a life time of a few microseconds thus creating high energy movements of the solvent that results in localized high energy shear forces as shown in following ***Figure 2*** [14-17]. The number of cavitation bubbles collapsing per second may well be in the millions hence their cumulative effect can be significant. Shock waves from cavitation in liquid-solid slurries produce high velocity-inter particle collisions, the impact of which is sufficient to convert the solid molecule into semi solid molecule. Thus, the ultrasonic energy may be effective to remove the sorbed contaminants, like heavy metals, from fine grained soils [18-20].

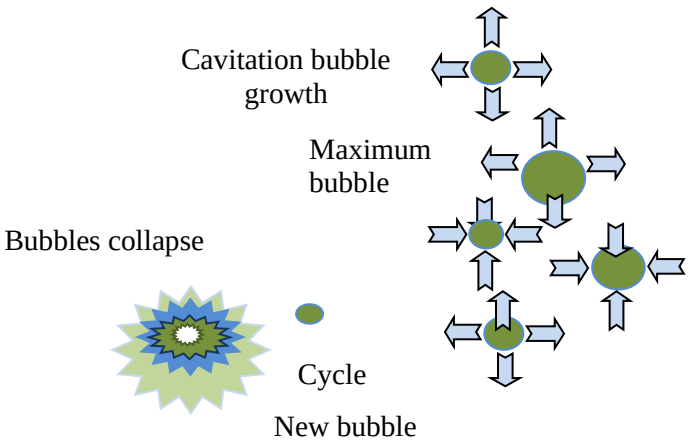


Figure 2: Cavitation and implosion phenomena in ultrasonic.

2.1 Application of Ultrasonic Technique in the Removal of Heavy Metals

The mechanism causing sonochemical effects in liquids is the phenomenon of acoustic cavitation. The chemical effects of ultrasound are derived from acoustic cavitation, which is a nonlinear process that serves as a means of concentration of the diffuse energy of sound in liquids. This high-energy microenvironment is induced by the extreme conditions generated during acoustic cavitation leading to the generation of high-energy species (radicals) [21-23]. Cavitation is the formation, growth, and implosive collapse of bubbles in a liquid. Cavitation collapse produces intense local heating, high pressures, enormous heating and cooling rates, and liquid jet streams (~400 km h^{-1}) [24].

In aqueous sonochemistry, chemical reactions occur at three regions:

(1) The cavitation bubble: Interior of collapsing bubbles where extreme conditions of temperature and pressure exist transiently, which induce chemical reactions yielding products that are typical of pyrolysis or combustion reactions in the gas phase.

(2) Bubble/solution interface: Interfacial regions between the cavitation bubbles and bulk solution where a high temperature (lower than that in the bubble core) is generated.

(3) Bulk solution: Where the free radicals, being produced in the interior of bubble and in the interfacial region, that survive migration from the interface can undergo reactions with solutes present in the bulk solution. [25-27].

2.2 Advantages of using sonochemical method over other

There are immense advantages of using sonochemical method over other, as under:

a. Sonochemical method is faster, therefore more productive in terms of time and energy consumption. Products synthesized by the sonochemical methods have greater stability.

b. The control of particle size is easier in sonochemical process, which is otherwise not possible by any other technique [28-29].

c. Preparation of amorphous products is possible, therefore, enhanced characteristics such as adsorption, catalytic activity etc. may be expected [30].

3. Decolourization by Adsorption Studies

Adsorption at various interfaces (liquid-gas, solid-gas etc.) has been a serious matter of study among the scientists from the beginning and specially during the last century. Among the physico chemical processes, adsorption technology is considered to be one the most effective and proven technology having potential application in both water and waste water treatment [31-32]. Adsorption is a rapid phenomenon of passive sequestration and separation of adsorbate from aqueous/gaseous phase on to solid phase. Decolourization is a result of two mechanisms- adsorption and ion exchange and is influenced by many factors including colour/sorbent interaction, sorbent surface area, particle size, temperature, pH and contact time [33-34]. The new classes of solid adsorbents have been developed during the last two decades such as activated carbon fibres and carbon molecular sieves, fullerenes and heterofullerenes, microporous glasses and nanoporous both carbonaceous and inorganic materials

(Dabrowski 2001) [1]. Nanostructured solids have also become very popular in science and technology due to their sorption, catalytic, magnetic, optical and thermal properties [35].

Adsorption studies are based on generally two types of adsorption processes:

- **Physisorption or Physical adsorption** – it arises due to the van der Waals interactions between adsorbate and adsorbent.
- **Chemisorption or Chemical adsorption** – it arises due to chemical interactions between adsorbate and adsorbent.
- **Mechanism of adsorption -** Adsorption is a three-step process. At first the adsorbate diffuses from fluid stream to the external surface of adsorbent. Secondly the adsorbate shifts to the pores of the adsorbent particles. Majority of adsorption occurs in these pores because of their large surface area. Finally, the molecules adhere to the surface area of pores [36-37].

3.1 Advantages of adsorption techniques: Adsorption is more advantageous than other techniques (Dabrowski 2001) due to:

- ✓ Low operation cost
- ✓ High flexibility
- ✓ Simple design and operation
- ✓ Easy automation
- ✓ Lack of sensitivity to toxic pollutants
- ✓ Capability of operation at very low concentration
- ✓ Environmentally friendly
- ✓ Less investment in terms of initial cost

4. Cane Sugar Colourants

This general term ‘colourant’ has been coined by Judd (1952) in order to indicate material which is either a dye (a compound which absorbs light with neglible scattering and a pigment (a compound which absorbs light with scattering). The colourants are among the most troublesome impurities in the production of white cane sugar. Despite the diversity of colourants in sugar solutions, presently, colouration is assessed by measuring absorbance at 420 nm as per ICUMSA protocol [38-39].

Like polyphenols, ***amino acids*** are colourless in sugarcane juice but produce colour while processing. The amino compounds react with reducing sugars and the reaction products formed; affect the quality of sugar in respect to its colour. Agarwal and Johary (1976) have reported the kinetics of the production of melanoidins. A reaction between amino acids and glucose has been also studied in details with reference to colour formation in sugar crystal. Ghule (1986) have analyzed number of plantation white sugar samples for their total amino acid contents [40]. Amino acids are also contributing to colouration of white sugar. They are responsible for colour deterioration during storage. Estimation of amino acids shows that there is relation between amino acids contents and colour of sugar (Reinfield *et al*, 1982) [41]. An average value of amino acid is about 60 mg/kg. The amino acid contents against ICUMSA colour index show that colour of sugar apparently increases with amino acid contents. The sugar samples having colour index below 80 ICUMSA units contain minimum 32 mg/kg and maximum 95 mg/kg of amino acids (Keskar et al,1990) whereas above colour index of 80 ICUMSA units the minimum and maximum amino acid contents are 75 mg/kg and 150 mg/kg respectively [42]. Probable mechanism of colour formation (Gross *et al*, 1976) on reactions in the presence of amino-acids is shown in Figure 3. The main sugarcane amino acids and their chemical structure are given in Table 2.

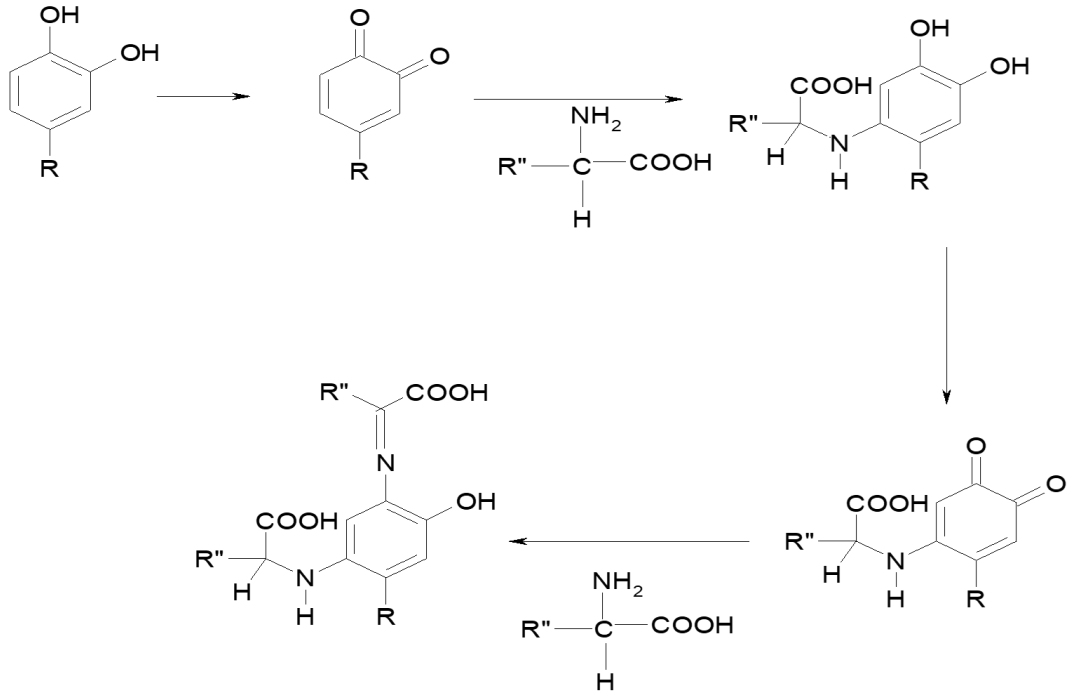
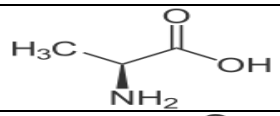
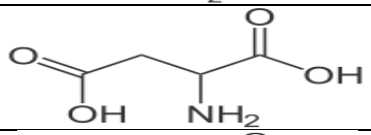
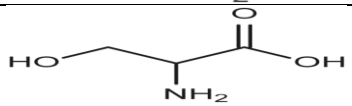
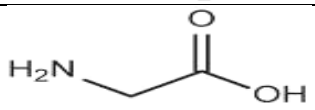
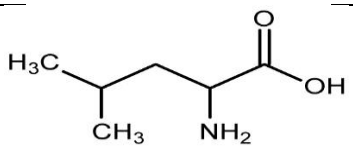
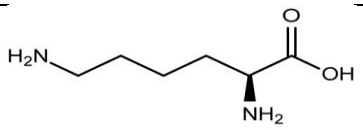
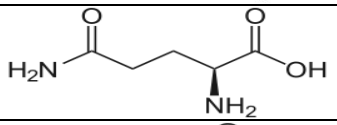
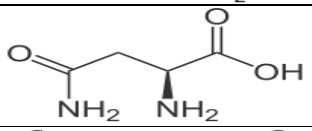
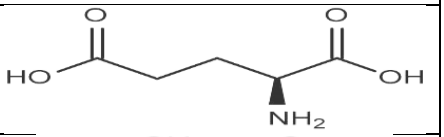
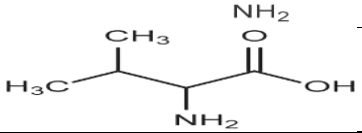
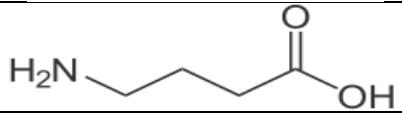


Figure 3. Probable mechanism of colour formation on reaction in the presence of amino-acids [43]

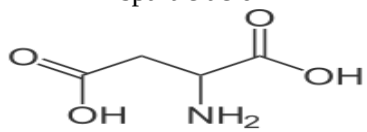
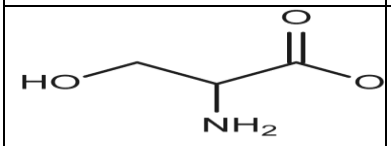
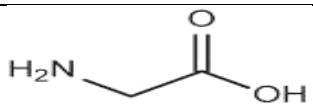
Table 2: Sugar Amino Acids ((West and Hull, 1973) [44]

S. No.	Amino Acids	Chemical Structure
1	Alanine	
2	Aspartic acid	
3	Serine	
4	Glycine	
5	Leucine	
6	Lycine	
7	Glutamine	
8	Asparagine	
9	Glutamic acid	
10	Valine	
11	γ Aminobutaric acid	

4.1 Physico-Chemical properties of the sugarcane amino acids (SAA) selected to study for adsorption

Aspartic acid, Serine and glycine were chosen as representative selection of amino acids (AA) commonly found sugar cane. The basic information concerning amino acids selected for study are included in ***Table 3***.

Table 3: Physico-Chemical Properties of the sugarcane amino acids (SAA)

Amino acids	Melting Point (°C)	pKa at 25°C	Aqueous solubility at 25°C (g/100ml)	Density in (g/cm^3)	Isoelectric point (pI)
Aspartic acid 	270	1.99 and 3.90 (carboxyl), 9.90 (amino)	0.45	1.7	2.98
 Serine	246	2.21 (carboxyl), 9.15 (amino)	Slightly soluble	1.603	5.68
 Glycine	233	2.34 (carboxyl), 9.78 (amino)	24.99	1.607	6.06

5. Research Attention

Biosorption is a green approach which uses plant materials as effective adsorbents for treatment of waste water. It is a property of living or dead biomasses to bind and concentrate metal ions from solutions. It is a form of adsorption process involving the removal of ions from liquid phase onto solid biomass material. Some biosorbents are competitive with existing non-biomass-based treatments [45]. Most of the plants have the potential to absorb the mineral salts and metal ions through their roots and then store them as organic minerals while some plant parts have the ability to adsorb salts and metal ions onto their surfaces [46]. A lot of research has been done on using plant-based materials as biosorbents; some of the biosorbents and adsorbent materials reported in the literature are presented in the ***Table 4*** below:

Table 4: Biosorbents/Adsorbent materials/Techniques used for sugar decolourization reported in the literature [47-59]

S. No.	Biosorbents /Adsorbent materials /Techniques	References
1.	Rice Husk (Activated)	Ahmedna et al., 1997
2.	Sugarcane Bagasse Pith	Ahmedna et al., 1997
3.	Bagasse Bottom Ash	Simaratanamongkol et al., 2010
4.	Defecation, Sulfitation and Carbonation	Michael et al., 2010
5.	Functionalized Accurel	Kaman Singh et al., 2011
6.	Activated Carbon	Nasehi et al., 2012

7.	Modified Sugar Beet Pulp	Hasan et al., 2012
8.	Activated Carbon	Zhang et al., 2012
9.	Activated Mustard Cake	Kaman Singh et al., 2014
10.	Activated Corn Cobs Powder	Ram Bharose et al., 2014
11.	Activated Wheat Husk (AWH)	Sudhir Kumar Verma et al., 2014
12.	Adsorbent Chromatographic Column	Manarim et al., 2016
13.	Powdered Carbon	Hind et al., 2018
14.	Activated Charcoal	Shikare Rasika et al., 2018
15.	The effect of high intensity ultrasound (HIU) on the kinetics of crystallization of sucrose	Kaman Singh et al., 2019

6. Phytoremediation

Activated carbon from agricultural by-products has the advantage of offering an effective, low cost replacement for existing bone char or coal-based granular activated carbon (GAC). This is a new approach for the treatment of contaminated water or soil. Phytoremediation means the use of plant-based materials for remediation of wastewater or polluted soil. Scientists and researchers are now focusing on search of plant materials that would efficiently remove contaminants from the wastewater. Phytoremediation is used in adsorption processes for more efficient removal of metal ions and TDS from the wastewater [60]. These materials are locally available, low cost, and are environmental friendly.

6.1 Selection of Waste Material

- **Sugarcane Bagasse Ash (SBA)**

Sugarcane bagasse Ash (SBA), a waste material generated in the sugar industry, is being indicated as causative agent of serious environmental pollution, which calls for an urgent need to develop ways of handling the waste. Bagasse ash mainly contains alumina and silica. Sugarcane bagasse ash is an important by-product of the sugarcane industry and most of it is burnt to produce steam and electricity in a co-generation plant at the ethanol factory. The sugarcane bagasse ash is the result of the bagasse combustion which mainly consists of high amount of silica (SiO_2) and unburned carbon. It's utilization as an adsorbent as well as mineral admixture in cement and concrete has also been examined [61]. Ash contains high amount of unburnt matter, silicon, aluminum, iron and calcium oxide but the ashes obtained directly from the mill are not reactive as these are burnt under

uncontrolled conditions and at very high temperatures [62]. The ash, therefore, become an industrial waste and poses disposal problems.

- **Rice Husk Ash (RHA)**

Rice husk ash are an agricultural waste material, which is easily available, cheap and economically advantageous. Rice husk ash is an undesirable agriculture mass residue. In India, is a by-product of the rice milling industry. It is one of the most important agricultural residues in quantity. It represents about 20% of the whole rice produced, on weight basis of the whole rice [63]. It was chosen because of its granular structure, chemical stability and its local availability at very low cost and there is no need to regenerate them due to their low production costs. The main constituents of rice husk are: 64% volatile matter, 12-16% fixed carbon and 15-20% ash. The rice husk compositions are: 32%, cellulose, 21.44% lignin, 21% hemicelluloses, 8.11% water and 15% mineral ash [64].

- **Corn Cob Ash (CCA)**

Corn cob is a lignocelluloses material composing of cellulose, hemicellulose and lignin (Vaughan et al, 2001) thus by carbonizing the precursor a porous carbon adsorbent would be obtained (Rahman *et al.*, 2005). About 11.5 million tons maize is produced in our country annually. Therefore, the corn cobs are easily available free of cost. Several researchers have reported developing activated carbon from corn cobs, but the surface areas were relatively low and the physical adsorption more energy demanding. Different values of surface areas were reported some of which are a value of 437 m^2/g, 664, 850, and 700 m^2/g, 608 and 897 m^2/g, 1014 and 1063 m^2/g, depending on the carbonization [65]. The surface of the corn-cobs can be modified with metal ions (Patel and Sudhakar, 2004) to attract anions (sugar colourants) from aqueous solution [66].

Objectives

- The proposed work is to examine the removal of sugarcane amino acids (SAA) from aqueous media using low-cost agricultural based green adsorbent materials developed from agricultural by-product-based waste materials (***Sugarcane Bagasse Ash, Rice Husk Ash and Corn Cob Ash***) in the presence and absence of ultrasound (US). Raw materials selected for the synthesis of green adsorbent materials like Sugarcane Bagasse, Rice Husk and Corn Cob are abundantly and cheaply available.

- The effect of operating parameters such as initial concentration of sugarcane amino acid, pH, particle size, contact time, rpm, temperature, and adsorbent dosage for the removal of sugarcane amino acids (SAA) proposed to be studies.
- Desorption studies will also be considered to make the proposed green adsorbent economical.
- Adsorption behavior is to be analyzed using Langmuir, Freundlich and Temkin isotherm models.
- The kinetic and the mechanism studies of adsorption will also be examined on the model of Weber-Morris and Boyd.
- The feasibility of sorption process in the environmental conditions, thermodynamics study will be carried out by using Gibbs free energy, Enthalpy and Entropy parameters.

Plan of Work: At a Glance

❖ ***Preparation of green biosorbent*** *(Singh et al., 2014 & 2019) by using following agricultural byproducts-*

- Sugarcane Bagasse (SB)
- Rice Husk (RH)
- Corn Cob (CC)

❖ ***Characterization of the bio-sorbents-***

✓ Field-Emission Scanning Electron Microscopy (FE-SEM)

✓ Energy dispersive X-ray spectroscopy (EDX)

✓ Fourier-Transform Infra-Red Spectroscopy (FTIR)

✓ X-Ray Diffraction Technique (XRD)

✓ Brunauer-Emmett-Teller (BET) Analysis

✓ Thermo Gravimetric Analysis (TGA)

✓ Differential Scanning Calorimetry (DSC)

✓ Atomic Force Microscopy (AFM)

✓ Dynamic Light Scattering (Zeta Sizer)

❖ ***Study of following parameters on adsorption-***

✓ Effect of pH

✓ Effect of contact time

- ✓ Effect of temperature
- ✓ Effect of adsorbent dosage
- ✓ Effect of particle size
- ✓ Effect of initial concentration of sugarcane amino acid
- ✓ Effect of rpm (rotation per minutes)

Experimental Conditions for Adsorption

Adsorption efficacy at laboratory scale using standard practices would be carried out in batch experiments under various experimental conditions are described in the figure 4. Evaluation of sorption and regeneration efficiency is described in the figure 5.

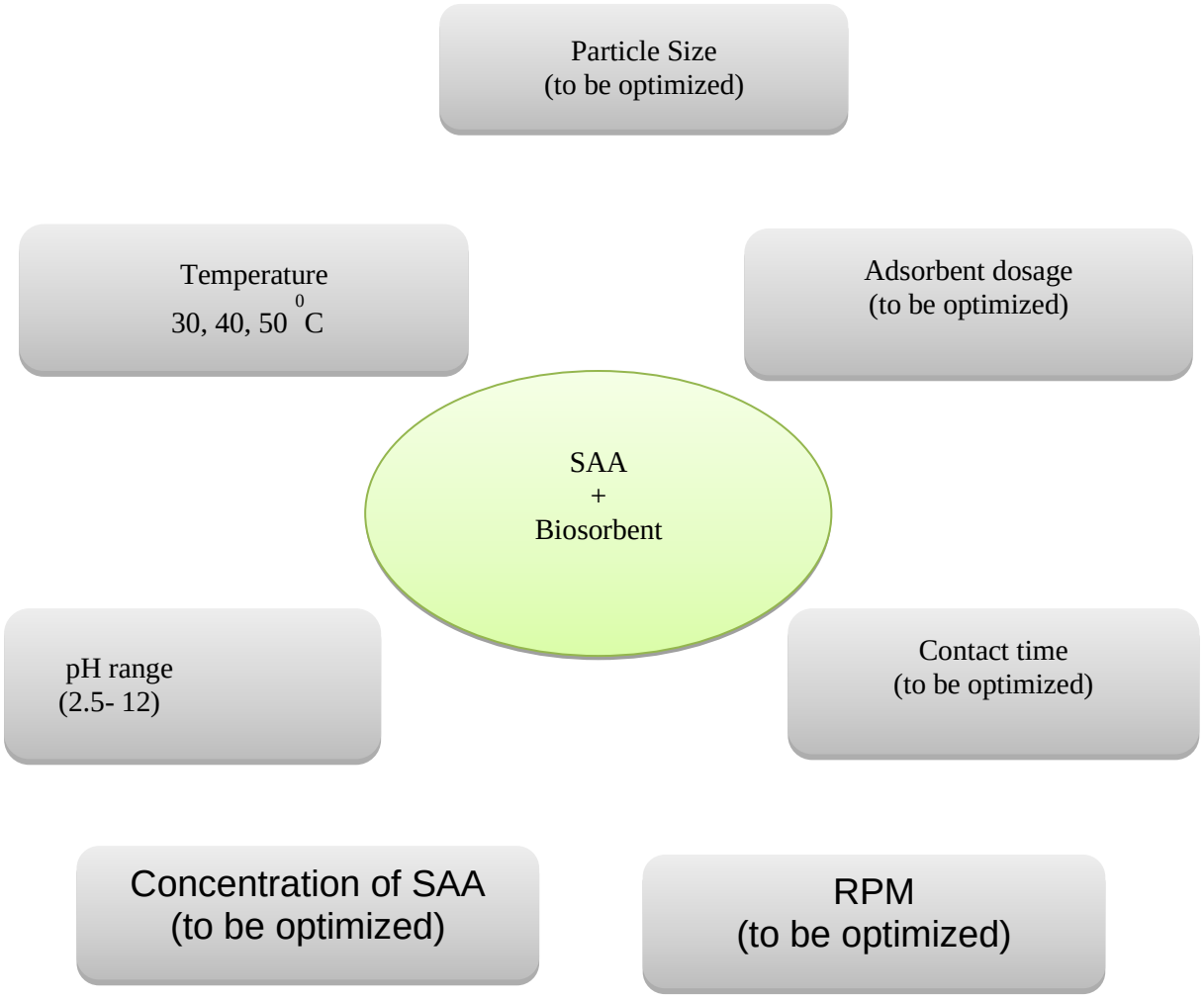


Figure 4. Experimental Conditions for Adsorption

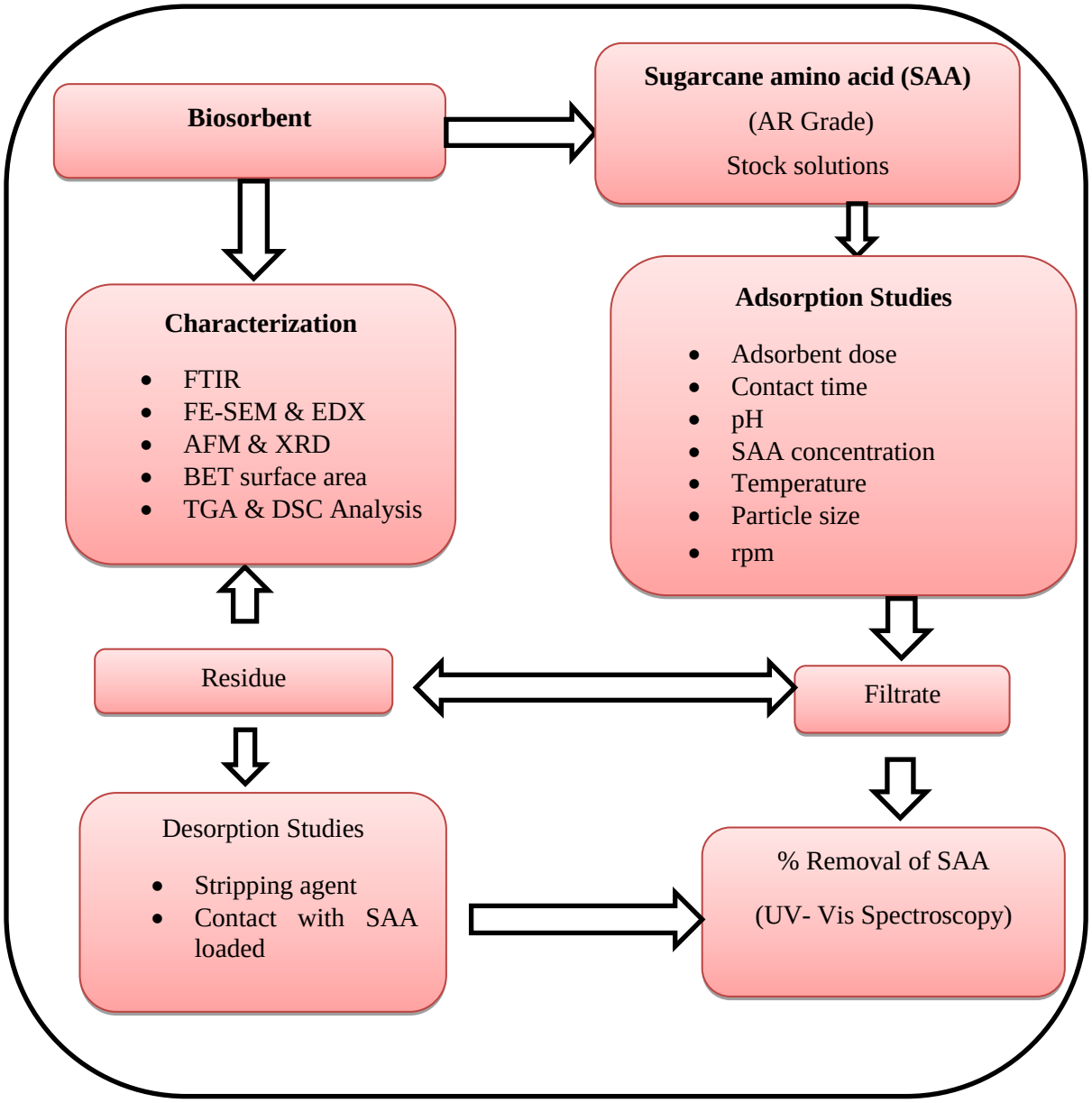


Figure 5: Evaluation of Sorption and Regeneration Efficiency

Methodology used for Sugar Solution Colour Measurement

Analytical potential of the biosorbent is assessed in batch mode and adsorption experiments will be performed. "ICUMSA" (International Commission for Uniform Methods of Sugar Analysis) is a worldwide body which brings together the activities of the National Committees for Sugar Analysis in more than thirty-member countries. An ICUMSA rating is an international unit for expressing the purity of the sugar in solution and is directly related to the colour of the sugar. The industry standard sugar solution colour measurement is the (ICUMSA) colour method [28].

The absorbance of the test solutions will be recorded by using UV double beam spectrophotometer. The colours of the sample will be determined using the ICUMSA protocol. ICUMSA colour is an indication of overall colour of sugar solution. The colour will be calculated as follows:

$$\text{I.U.} = \frac{Abs \times 1000}{b \times C}$$

b = cell length (cm)

C = Sugar concentration (gm/ml)

ICUMSA colour (I.U.) is an indication of the overall colour of the sugar solution.

The Colour Removal (CR%) is expressed as follows:

$$CR\% = \frac{I.U_i - I.U_f}{I.U_i} \times 100$$

$I.U_i$ = Initial ICUMSA colour

$I.U_f$ = Final ICUMSA colour

Proposed Mechanism of Adsorption of Amino acids

The main forces, which govern adsorption, are hydrophobic and electrostatical interactions between amino acid and solid surfaces (Figure 4). In addition, the structural stability of the amino acid is very important during the process of adsorption; on hydrophobic surfaces amino acid undergoes conformational changes. Amino acids are comprised of basic amino and acidic carboxyl functional groups as well as a characteristic side chain (John *et al*, 2005). At high pH, the carboxyl group tends to be dissociated, giving the compound a negative charge. At low pH, the amino group, as well as the overall molecule, becomes positively charged. At an interim pH known as the isoelectric point, aminoacid in solution has, on average, a net charge of zero. At this point, a solution contains positively and negatively charged amino acid ions in equal quantities. This is represented for the simplest amino acid, glycine, by the following equilibrium equation:

$$H_2N\text{-}CH_2COO^- + H^+ \leftrightarrow H_3N^+\text{-}CH_2COO^-$$

(Anion) (Zwitterion)

$$H_3N^+\text{-}CH_2COO^- + H^+ \leftrightarrow H_3N^+\text{-}CH_2COOH$$

(Zwitterion) (Cation)

In alkaline solution, the amino acid will be present primarily as the COO^- anion but as acidity increases the zwitterionic form will become predominate. Finally, in stronger acid, the NH_3^+ ion will predominate. Mode of interaction of amino acids onto solid surface is shown in Figure 6.

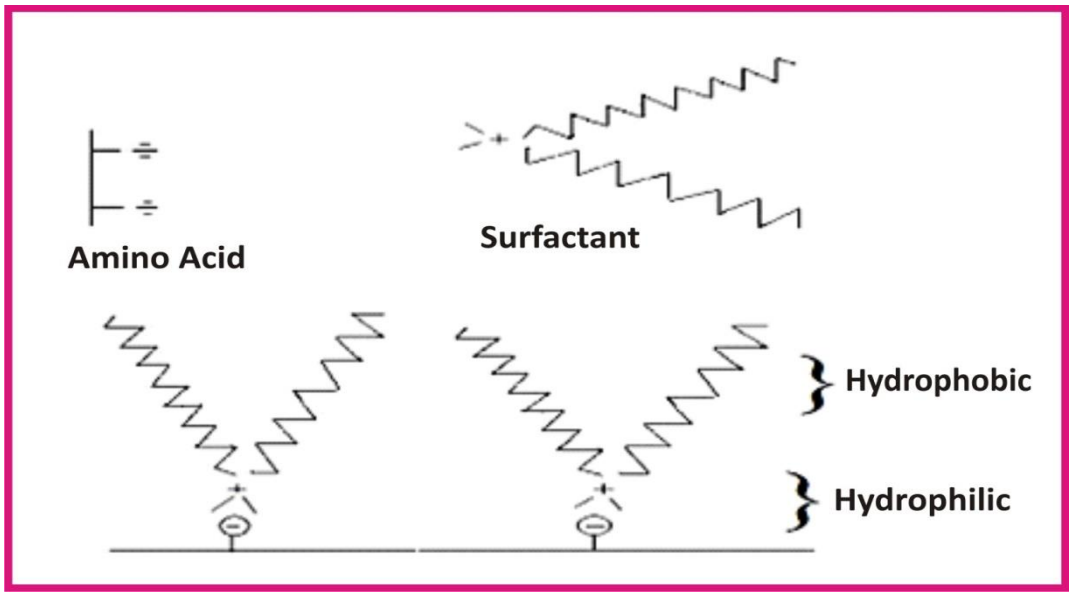


Figure 6: Mode of interaction of amino acids onto solid surface [54].

Measurement of Amino Acids

The ninhydrin reaction, one of the most important method of detecting amino acid, both technically and historically, has been conventionally used to detect their microgram amounts. Ninhydrin, which is originally yellow, reacts with amino acid and turns deep purple (Figure 7).

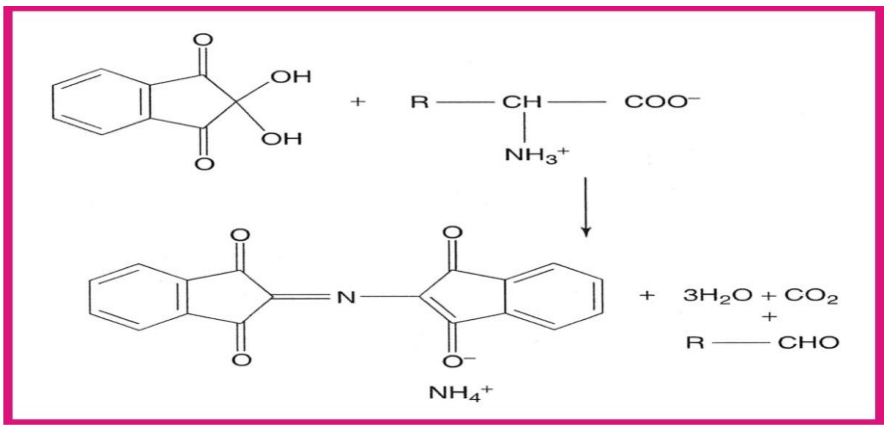


Figure 7. Reaction of ninhydrin with an amino acid, producing the purple-blue product [55].

Ninhydrin will react with a free alpha-amino group. This group is present in all amino acid, proteins or peptides. Whereas, the decarboxylation reaction will proceed for a free amino acid, it will not happen

for peptides and proteins. Theoretically only amino acids produce colour with ninhydrin reagent. Under appropriate conditions, the colour intensity produced is proportional to the amino acid concentration. The primary amino groups react with ninhydrin to form the purple colour dye now called Ruhemann's Purple (RP) was discovered by Siegfried Ruhemann in 1910.

Significance of the Work

The research findings may be used for the removal of sugarcane amino acids or raw sugar colour (dark brown) from aqueous media by green routes. The proposed research work has some important implications in the sugar refining process: -

1. It is aimed to obtain the fundamental data on adsorption of sugar colour from aqueous sugar solution.
2. The obtained results could be applied in sugar industries in various separation processes in addition to removal of sugarcane phenolic acid or sugar colour.
3. The present work is proposed to be undertaken to explore the feasibility of new adsorbents to uptake of sugar colour.
4. The present project may to offer very cheap, efficient and useful adsorbents for effective removal of sugar colour from aqueous sugar solution.
5. To develop new technical process for sugar industries which is beneficial for process control and significant energy saving.

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